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BRIGADE-SURGEON G. KING, M.B., LL.D., F.R.S., C.I.E.,
DIRECTOR OF THE BOTANICAL SURVEY OF INDIA.



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A NOTE ON INDIAN WHEAT-RUSTS.

BY

D. D. CUNNINGHAM and D. PRAIN.



CALCUTTA:

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VOLUME I.

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A NOTE ON INDIAN WHEAT-RUSTS.

By D. D. CUNNINGHAM and D. PRAIN.

During the cold season of 1895-96, while one of us was engaged in conducting certain experimental cultures of wheat at the Government Farm, Shibpur, an opportunity was afforded of partially investigating some of the phenomena connected with "rust" in wheat. The results obtained, as will presently appear, are neither final nor, so far even as they go, complete. But if they do not clear up the difficulties that surround this subject, they seem to narrow in some degree the field of enquiry; in this respect therefore they may prove of some general interest and may perhaps to a certain extent be of use. The present note, which has been prepared in compliance with an order issued to Dr. Prain by the Government of India through the Government of Bengal, contains an account of our observations.

Owing to the exigencies of routine work at the Experimental Farm and, in some instances, owing to delay in the arrival of samples, the sowings were made rather late in the season. Of 82 patches, in which as many samples were tried, 27 were sown on October 31st, 1895; 21 on November 3rd; 11 on November 13th, and the remainder on November 25th. In each case the wheat was sown in parallel drills in long narrow plots.

In one of the plots of the third sowing it was noticed for the first time on January 14th, that some of the plants had become "rusted"; about six plants in each of three rows in the centre of the patch were then apparently affected. Two days later the "rust" was evident in adjacent patches; within a week it had appeared in every part of the wheat-field; in less than ten days it was not possible to find a single plant entirely free from "rust."

The subject of "rust" on Indian wheat is for both of us one of interest because of the attention it received from our lamented friend, the late Dr. Arthur Barclay. So soon therefore as one of us had noticed the presence of "rust" in this wheat-field and the other had ascertained that its structural and metric characters seemed to be those indicative of the Indian "rust" identified by Dr. Barclay with *Puccinia rubigo-vera* (Journal of Botany, vol. 30, p. 46, 1892), it became our object, if possible, to ascertain the source of the blight.

Attention was directed to the onset of the attack by the appearance of the affected plants. The leaves that form a tuft close to the soil and surround the bases of the culms seemed within 24 hours to have become suddenly wilted and yellow, the soil in a circular patch round the base of the plant having at the same time become of a rusty-red colour. Close examination of the plants showed that the blades of these yellow and suddenly-wilted leaves were completely inrolled from the margins; on their being flattened out it was seen that the upper surface of the blade was closely covered by an eruption of small circular orange-red pustules; the rusty hue imparted to the soil in the immediate neighbourhood of the plant was found to be due to the shedding of uredospores from these pustules in quantities sufficient to form a thick almost continuous surface-coating. The lower culm-leaves were still green; their upper surface was, however, covered with a crop of uredosporic pustules, and they showed that the wilting process had commenced because the edges of the leaf-blades were already slightly inrolled. The higher culm-leaves were in much the condition of those below, except that the pustules were more sparsely scattered and the edges of the leaf-blades were not yet at all inrolled.

The limitation of the uredosporic pustules of this rust to the upper surface of the leaf-blades observed in the case of the plants first attacked was found in the course of subsequent numerous and prolonged examinations to be an almost unbroken rule. It was not at all common, though instances did occur, to find a pustule that occupied the whole thickness of the leaf, and that burst through the epidermis of both its surfaces. But to find a pustule breaking through the lower surface only was an extremely rare occurrence. In keeping with this observation also is the fact that it seems very rare with this particular "rust," and then only in very badly affected plants, to find uredosporic pustules on the outside of the leaf-sheath. Instances of this were, however, met with both at Shibpur and elsewhere, and in one or two instances pustules even appeared on and burst through the epidermis of the stem itself. Not a single instance of the occurrence of uredospores on the pales or glumes or within the flower was met with in the case of this rust. But perhaps its most noteworthy feature, so far at least as this particular outbreak at Shibpur is concerned, was the entire absence of teleuto-spores. In spite of prolonged and repeated systematic search for these, during the time the wheat was in the ground, they were never met with.

The samples of wheat sown at Shibpur included examples of all the "races" or "strains" of wheat usually cultivated in the province. These races are not particularly numerous, four or five being probably the limit so far as Bengal is concerned. The majority of the samples, however, belonged to four "races"; (1) a wheat with broad leaves and soft, starchy, white grain; (2) one with broad leaves and hard, glutinous, grey grain; (3) one with narrow leaves and soft, starchy, pale-red grain; (4) one with narrow leaves and hard, glutinous, darkish-red grain. The samples were not sown in any particular order as regards place of origin or as regards race. But while every patch became more or less rusted, the blight was observed to affect more seriously the soft starchy wheats, whether white or red, than it did the hard glutinous ones. A rather curious exception to this rule was noted in the case of one patch, the wheat in which, though soft, starchy and white as to its grain, had narrow leaves like a red wheat. But there is apparently no real connection between breadth of leaf-blade and power of resisting "rust," for all save one of the "soft-red" wheats had narrow blades, and almost all were badly rusted as compared with the "hard-red" wheats. The exceptions were in every case samples that ripened early, and it was apparently its agreement with those samples in this respect, and not its similarity as regards narrowness of leaf that helped to protect the "white" sample already mentioned. So far as our observations at Shibpur go, they show that there is not, at all events in Bengal, any race of wheat that is immune against this particular "rust."

The samples of wheat sown were of the usual Indian character—carelessly collected and much mixed with seeds of pulses and of other cereals. As a consequence when the crop appeared, numerous plants of barley were to be found scattered throughout the field. Our attention was at once attracted to the fact that this "rust" apparently does not affect barley. As the point is one of some importance from its bearing on the assumed identity of this Indian "rust" with the *Puccinia rubigo-vera* of Europe, a close and systematic drill to drill inspection of the whole field was instituted in connection with the search for teleutospores. In no single instance was a barley-plant at Shibpur, at any period of the season, affected by this "rust."

In most instances the mode of attack was exactly as in the plot first affected. A whole line of wheat-plants that on a given morning appeared still exempt from "rust," showed after a two-days' interval the "crown" of leaves at their bases wilted and rusted from end to end of the drill; the ground between the plants of that drill, at times

even the space between adjacent drills, became at the same time of a uniform rusty-red colour from the layer of shed uredospores that coated it.

In some instances, however, and this was more particularly the case with the glutinous wheats, the blight seemed to affect the higher culm-leaves either before or at the same time as it appeared on the lower stem-leaves and on the tuft of leaves at the base. The early portion of the period—latter half of January and first half of February—to which our observations at Shibpur refer, was marked by those morning river-fogs characteristic of the season in the Gangetic delta. On such a morning the drops of water that studded the upper surface of the leaf-blades, both of wheat and barley, had a tinge of orange imparted to them by reason of the number of uredospores held in suspension within them. The slight breeze that, as a rule, accompanies the “lifting” of such a river-fog is thus clearly sufficient to carry these spores from one plant to another, while the moisture deposited on the leaves during the fog provides a means of arresting the spores. Whether the uredospores thus arrested in these dew drops actually did affect the wheat or not, it is certain that, if they were capable of affecting either the wheat or the barley, ample opportunity was afforded them of so doing.

During the first careful conjoint survey that was made by us of this wheat-field, it was found that *Launea asplenifolia* DC.,—a common weed in Bengal, where it bears the name *tikchana*, and locally abundant about Shibpur—carried on the upper surface of its leaves in great quantities the uredospores of a *Puccinia* which seemed as if it might possibly be the one present on the wheat. In another part of the field it was found that malformed shoots of the same *Launea* bore what were apparently the æcidial fructifications of the same blight. Presently too it was discovered that the under-surface of the leaves of this *Launea* carried, in some cases, the teleutospores of obviously the same *Puccinia*.

Minute examination having shown that it is not possible by structural or metric characters to differentiate the uredospores of the *Puccinia* present on the wheat from those of the *Puccinia* present on *Launea asplenifolia*, and having thus rendered it, under the circumstances, possible that the two may be specifically identical, it became necessary to undertake experimental cultures in order to confirm or to disprove their identity. The lateness of the sowings and consequent lateness of appearance of the rust on the wheat at Shibpur and of the discovery of this *Puccinia* on *Launea asplenifolia*

rendered it impossible to carry the necessary experiments, which were initiated by one of us, to completion. As much, however, was done as it was possible, during what remained of the cold season, to do. In the meantime it was essential also to ascertain with some approach to accuracy whether the phytogeographical area occupied by this *Launea* in any way coincides with that in which wheat is grown in India. And as the evidence to be derived from specimens of the plant preserved in the Calcutta Herbarium was not conclusive, one of us was ordered by the Director of the Botanical Survey to visit certain representative wheat-growing districts and to ascertain, on the spot, the conditions there as regards the wheat, the rust, and the *Launea*. As some of the results of this investigation tended to increase rather than to diminish the difficulties that beset the whole problem, it appears better to give an account of these results *before* describing the culture experiments, although as a matter of fact the two investigations were being conducted simultaneously.

Launea asplenifolia DC., the species that was the object of this special search, is a member of the natural order *Compositæ*, tribe *Cichoriaceæ* § *Lactuceæ*, with an extremely slender and brittle perennial rootstock of great length as compared with the size of the plant; this rootstock can be followed almost vertically downwards to a depth of from 2 feet to 30 inches, without any sensible diminution in thickness, but we have never been able to satisfy ourselves that the whole rhizome has been obtained; on being broken the stock exudes a pure white latex, as do the leaves and stems. Towards the top the rootstock usually divides into several heads, each head being crowned with a rosulate tuft of lyrate-pinnatifid leaves 3—6 inches long. These leaves lie close to the ground in plants that grow in the open field exposed to full sunshine. When, however, the plant is growing in grassy places or amongst thick standing grain some of the internodes of the crown become, as a rule, more or less elongated; giving rise variously to a rosulate arrangement at the base followed by a slender stem with scattered leaves above this rosette; to a stem with the leaves scattered throughout; or to two or more irregular rosettes separated by distinct intervals. When growing in grain or amongst grass the leaves are delicate and thinly membranous during the cold-weather months. When growing in the open, however, the leaves are much thicker and firmer, sometimes having an almost fleshy consistence, and are, as a rule, paler green in colour. This last feature, however, is not at all universal; at times plants growing exposed to the full effects of sun and wind have a dark, purplish red tinge imparted to the leaves, especially on the under-surface. The

plant comes into flower in February in Bengal, Behar, Central India, and Rajputana. In Oudh and the Punjab it is about a month later of flowering. It fruits in Bengal about the middle of March. For a description of its yellow flowers and its fruits, on which its identity depends, but which, its identity being established, do not interest us in this connection, reference may be made to systematic treatises. The inflorescences, however, on which these flowers and fruits are borne consist of branches that arise in the axils of from one to five of the leaves nearest the centre of the crown. The corresponding buds in the axils of those leaves that do not subtend inflorescences remain as small bodies covered with rather longish white hairs. By the middle or end of the hot weather, as a rule, all trace of the crown and its leaves has disappeared; these rhizomes that in May and June are still crowned with leaves have their leaves, even when the plant is growing in shady grassy spots, thick and fleshy as in the case of plants growing in the open sun in the cold weather.

In diseased plants the uredospores appear in rusty-red pustules that are almost always confined to the upper surface of the leaves; this is not, however, universal, for sometimes they occur on the lower surface of the leaves; occasionally they are to be found, though this is very rare, in patches that burst through the epidermis of the rachis and branches of the inflorescence. These uredosporic pustules exhibit essentially the characters exhibited by the corresponding pustules on the leaves of wheat, but as a rule they are of larger size.

The teleutospores occur perhaps most frequently on the under-surface of the leaves; it is, however, much more usual to find teleutospores on the upper surface than to find uredospores beneath. And it is not at all essential that the two be present together; in certain cases indeed it was impossible to find teleutospores on the *Launea* and *vice versa*. The presence of a teleutosporic patch is usually foreshadowed by pallid discoloration of a circumscribed area on the leaf; over this spot the epidermis very soon gives way; either generally, in which case there is a large irregular black patch of exposed teleutospores; or in a central medium-sized patch with a series of small black patches arranged round the central one in 3—5 concentric rings. Not uncommonly black teleutosporic patches are to be met with along the rachis of the inflorescence; these are always much smaller than the patches on the leaves, and sometimes the epidermis above them remains intact.

The æcidial fructifications sometimes make their appearance in what, from their position with reference to the rhizome and the other

leaves, are leaves of the normal rosette. In such a case the leaf undergoes a very rapid growth in thickness and often in length and breadth, assuming an etiolated and sickly appearance and having the indentations along its margin obscured or obliterated. Occasionally also the rachis of an inflorescence is found to be thickened in this manner and to assume the characteristic etiolated appearance that indicates the condition. But much more usually neither the leaves of the rosette nor the normally produced flower-branches are at all affected; one or more of the buds already mentioned as remaining undeveloped in the axils of the outer leaves of the rosette suddenly develop into diseased shoots, occasionally bearing malformed flowers, but much more usually having only malformed leaves. And sometimes it is found that in cases where a rhizome has several heads the others may be quite normal or at most bear only uredospores or teliospores or both, while one head is entirely malformed from the point where it rises from the ground, all its leaves and shoots being converted into æcidia-carrying organs.

Whatever the precise morphological origin of the part may be, its consistence is similar and its history is identical. A shoot of the axillary type may by the fourth day of its special growth have become 6 inches long; whatever size it may attain it does not after the fourth day appreciably increase in size. On the third day the etiolated surface shows the presence of small papillæ scattered fairly uniformly over it, these by the fifth day appear as an eruption of round miliary bodies of a fine purple colour which presently open at their tips and become converted into small cups filled with pale lemon-yellow æcidiospores. These æcidiospores could be seen occasionally dispersed by puffs of wind; unlike the uredospores they did not mix with water.

Sometimes the malformed shoots with æcidial fructifications remained, after the dispersal of the æcidiospores, as shrivelled very fragile structures. More usually, however, within three or four days of the ripening of the æcidia the whole shoot became soft, black and putrescent, sinking to the ground and rapidly "damping off;" the general health of the plant meanwhile remained apparently unaffected.

At Mozufferpur, selected as a representative locality for North Behar, which was visited on February 21st, the state of affairs as regards both wheat and *Launea* were very similar to those prevailing at Shibpur. The wheat was not however so badly affected by rust as in Lower Bengal: every plant was not affected and none were very severely attacked. The "rust" was here found in every case to be

confined to the upper surface of the leaf-blade. *Launea asplenifolia* was very common, and specimens were obtained in fields, in a patch of village-jungle, on the race-course, by the side of a high-road. In every locality it was affected by the *Puccinia* prevalent at Shibpur; uredospores were plentiful on the upper, teleutospores on the under surface of the leaves respectively; abnormal shoots with æcidial fructifications were everywhere very common.

A barley-field in which the individual plants seemed stunted and were far apart was examined, with some care. It was found that many of the plants were affected, though none apparently seriously so, by a "rust" that from the oval shape of its rusty patches and from the occurrence of these on the stem, the outside of the leaf-sheath and the underside of the leaf, as well as by the fact of its occurrence on barley at all, was evidently different from the rust identified by Dr. Barclay with *Puccinia rubigo-vera*. Later this same rust was discovered in an adjacent wheat-field on a wheat-plant. On being subjected to minute examination this rust was found to exhibit the structural and metric characters of the rust identified by Dr. Barclay with *Puccinia graminis*. One barley-plant was found affected by a pale lemon-coloured rust consisting of longitudinally arranged parallel lines of very small pustules containing uredospores. All that could be said regarding it was that it did not agree well with either of the other rusts.

The search for teleutospores on wheat of the blight prevalent at Shibpur was unsuccessful at Mozufferpur, and it is highly probable that no teleutospores were present. The *Launea* is here termed *titlia*; it is reputed an effective febrifuge. The name used for "Rust" is *harda*; the two rusts are not differentiated.

At Gaya, visited on 22nd February as a representative locality for South Behar, no blight of any kind was found on the wheat or on the barley. Here the wheat and barley-fields had very few weeds, none of these being perennials, and a very extended search for *Launea* was unsuccessful. At length in a gram-field, a considerable distance from any wheat, it was discovered and as usual was found to be abundant in the spot where it occurred. The plants were quite healthy; growing openly exposed to sun and wind their leaves were much thicker and firmer than in Lower Bengal at the same season, though not firmer than they become in Lower Bengal during May and June.

At Mogul Serai, North-Western Provinces, visited on 23rd February, no unequivocal example of wheat affected by Dr. Barclay's *Puccinia rubigo-vera* was met with. Nor in the barley-fields

examined were any plants unequivocally affected by Dr. Barclay's *Puccinia graminis* met with, though several good examples of the pale rust mentioned as occurring at Mozufferpur were encountered. Among the wheat plants, however, two were obtained that were unequivocally affected by the Indian rust supposed to be *Puccinia graminis*, showing in long oval pustules on the underside of the leaf. *Launea asplenifolia* was again found to be very local though quite plentiful when it occurs. Most of the plants were quite healthy; one however was manifestly affected on the upper surface of its leaves with uredospores exactly like those at Shibpur and Mozufferpur; many had teleutospores; like the Shibpur plants, usually only on the under surface, but occasionally on the upper surface as well; no æcidial fructification was met with. The *Launea* is here known as *gobi*; the rust as *gerhwi*. The name *titlia*, used at Mozufferpur for *Launea*, is here applied to a spurge, *Euphorbia dracunculoides*.

At Allahabad, which was next visited, on the afternoon of 23rd February it was found that wheat was little grown in and about the station; patches in a few compounds and along a narrow strip on the banks of the Jumna below the level reached by the river in the rains, being the only places available for search. The wheat and also the barley north of the Jumna was all quite healthy. *Launea asplenifolia* is not uncommon in gardens in the station; it was in every case quite healthy. It is here associated with another species, *Launea nudicaulis*, very like it in habit and in general appearance, but with much thicker and rather larger leaves finely serrate along their margins with minute white cartilaginous teeth, with rather larger flowers and with an ochre-coloured instead of a pure-white latex. This species also was perfectly healthy. On 24th February the area across the Jumna was examined. Here wheat was found to be this season entirely confined to the strip along the river bank mentioned above. It appeared very free from rust; only one small patch, near the upper limit of the belt, was found where about 20 plants were affected by the so-called "*Puccinia rubigo-vera*;" only uredospores were present. Associated with this patch was a single plant very considerably affected by the so-called "*Puccinia graminis*;" a second plant was found some distance off, and close to the water's edge, carrying the same rust.

Among this wheat no *Launea* was found; so soon however as the limit reached by the river in the rains was passed, *Launea nudicaulis* was found to be present and to be common. When the level ground at the top of the scarp was attained, this species gave place to *Launea asplenifolia* which was found to be plentiful. From this

point on to Naini, where the search ended, no wheat was found, and very little barley, none of the latter being diseased. *Launea asplenifolia* was quite plentiful throughout in level fields or where the slopes were gentle; on the steep sides of nullahs it was replaced by *Launea nudicaulis*. No diseased example of either species was met with. The rusts are not here differentiated; both are termed *gerhwi*: both the *Launeas* are known as *gobi*.

Jabalpur, visited on 25th February as representative of the Central Provinces, gave, like Gaya, no result. The wheat in this district was quite free from rust; the black cotton soil in which it is grown was extremely free from weeds of any kind; no *Launea* was found among the wheat. On the banks of nullahs and on the slopes of hummocks rising above the level of the black soil in the fields, also in gardens, both native and European, *Launea nudicaulis* was found, but never plentifully; no *Launea asplenifolia* was met with anywhere. The search here extended from Maharajpur on the Allahabad road (25th), to Mirganj and the Nerbadda in the opposite direction (26th February), and was everywhere equally unsuccessful. The cultivators were however thoroughly conversant with "rust;" the description given of its ravages and appearance concided very well with the appearance presented at Shibpur and at Mozufferpur. The name used for it was, however, *gerhwa* not *gerhwi*; the interest of this use of the opposite sex will be apparent in dealing with the names used in Rajputana.

On 27th February it was noted that on the sides of nullahs near Dhularia Railway Station, and in the station compound at Dharain Kundi, *Launea nudicaulis* was present; no *Launea asplenifolia* was seen. At Itarsi one wheat-field was visited; no rust was found. At Chandni neither *Launea* nor wheat were found.

On 28th February, at Khandwa, on rust was found on the wheat, and neither species of *Launea* was met with. The cultivators were quite conversant with "rust" which had, they said, been prevalent some seasons ago and which they know as *gerhwa*. Their description, however, differed very markedly from that given at Jabalpur, all who volunteered information insisting that at the last outbreak the rust was not confined to the leaves but was marked by an eruption of black specks on the glumes and pales. No barley was met with at Khandwa.

At Neemuch, visited on 29th February as representative of Malwa, the same black cotton soil that prevailed at Jabalpur and Khandwa was met with. Here also both the wheat and the barley were found perfectly free from rust. But *Launea asplenifolia*, which was not

met with at Jabalpur or Khandwa, was here, as in Bengal, local but very abundant where it occurred. The first field examined was full of the species, and nearly every plant was badly affected by the same *Puccinia* seen in Bengal and in North Behar. In this instance, however, no uredospores were found; teleutospores were very abundant and appeared to occur only in small spots arranged in concentric circles—a condition which occurred, but was not the most usual, in Bengal. Very few plants were quite healthy; of the diseased ones about 30 per cent. had æcidiosporic fructifications; these were here much less frequently borne on specially modified shoots than on distorted flowering branches; these branches much more frequently shrivelled up into brittle twigs than damped off. Continuing the search on 1st March, the local occurrence of the species was well seen from the fact that no *Launea asplenifolia* was obtained till a point was reached two miles away from the previous afternoon's patch, and three more miles had to be passed till another diseased patch was met with. As on the preceding day, the search failed to yield a specimen with uredospores and no rust was found either on wheat or barley. In one field a number of plants of *Launea nudicaulis* were found; though growing alongside of badly blighted *Launea asplenifolia* none of them were diseased. *Launea nudicaulis* was also found to occur on roadsides in the station itself. The name for both *Launeas* was again *gobi*; the name for the rust was *gerhwi* as at Allahabad, not *gerhwa* as at Jabalpur and Khandwa; the cultivators, however, use as an alternative the name *rori*, though not so commonly as the other.

The discovery of *Launea asplenifolia* diseased, on black cotton soil, leads to the suspicion, when its very local occurrence is taken into consideration, that it may only have been overlooked at Jabalpur and at Khandwa. Captain Pinhey, Political Agent at Neemuch, himself an enthusiastic botanist, very kindly assisted in the search of 29th February for *Launea asplenifolia*, and on visiting Ujain ten days later most kindly searched for it there, with the result of ascertaining that at Ujain it is as plentiful, and was this year as badly diseased, as at Neemuch. It therefore certainly extends as far south as to the latitude of Jabalpur, carrying the *Puccinia* with it.

At Ajmir, on March 2nd, none of the supposed *Puccinia Rubigo-vera* was found on the wheat. At a point 5 miles from Ajmir on the Jeypore road the supposed *Puccinia graminis* was found on a wheat plant; the same rust was found on a barley-plant in a field 2 miles south of Ajmir on the Nusserabad road. No *Launea asplenifolia* was found; *Launea nudicaulis* was here more plentiful than in any of the other places visited. It is known as *gobi*, and was without any disease. The rust is here *rori* or *roli*.

At Jeypore, visited on March 3rd, the soil in the fields was a much irrigated, fine blown-sand, extremely free from weeds. No *Launea asplenifolia* was to be found anywhere in the neighbourhood of the city. *Launea nudicaulis*, very rare in fields, is not uncommon on roadsides and in gardens. It was perfectly healthy, as were the wheat and the barley. On 4th March Chaudaspura, 17 miles from Jeypore on the Tonk road, was visited, Colonel Jacob having been so good as to point out that at this point the soft blown-sand gives place to a firmer soil. Here, after a considerable search during which *Launea nudicaulis* was found to be fairly common, a spot was reached in which *Launea asplenifolia* was extremely abundant. There was very little rust on the wheat, what there was being the supposed *Puccinia rubigo-vera* of Shibpur. *Launea asplenifolia* was, however, extremely affected; most of the plants carried teleutospores only; some, however, had uredospores as well. Aecidiosporic fructifications were apparently very rare, only one being met with; the aecidia were in this case borne on a malformed leaf, not on a specially developed shoot. The most interesting discovery here was, however, a plant of *Launea nudicaulis*, the species that in every other locality had been found to be healthy, with telēutosporic fructifications on its leaves. The two *Launeas* are known indifferently as *gobi*, the "rust" on wheat is known as *rori* or *roli*. The name *rori* or *rola* was also known, but it was found impossible either to substantiate or to refute the opinion mentioned by Dr. Barclay (Journal of Botany, vol. 30, p. 47) as prevailing in some quarters, that the feminine form *roli* is used for the supposed *Puccinia graminis*, the male form *rola* for the supposed *Puccinia rubigo-vera*. It is certain that some of the cultivators use the words indiscriminately and declare that both mean the same thing. Others, however, insisted that they were different. Fortunately for them, though perhaps unfortunately for the present enquiry, "rust" on the spot was hardly to be obtained. The little there was chanced to be the supposed *Puccinia rubigo-vera* which, according to the information obtained by Dr. Barclay, should have been *rola*; yet the inhabitants of the neighbourhood and the owner of the field insisted that it was *roli*.

At Rewari, March 5th, very little wheat but much barley was found; neither at all diseased. Here *Launea nudicaulis* is fairly common everywhere, and *Launea asplenifolia* as elsewhere is local but abundant where it occurs; neither *Launea* was at all diseased. From the cultivators it was ascertained that "rust" here is known under the name *rori*, but the word is not much used; the term employed is *khungi*; the *Launeas* appeared to have no name.

At Sirsa, March 6th, no rust on wheat; only one plant of *Launea nudicaulis* for which no name was obtained. "Rust" is here, the cultivators say, known only as *khungi*.

At Ferozepur, March 6th, "rust"—here known as *khungi*—was very common in patches. Though less universal than at Mozufferpur, it was much more severe in its effects. In appearance it much resembled the supposed *Puccinia rubigo-vera* of Bengal and Behar; here, however, teleutospore fructifications were plentiful, hardly a diseased plant being without some. The principal distinction between this "rust" at Ferozepur as compared with the rust met with at Shibpur, lay in the greater frequency with which the outside of the culms and of the leaf sheaths were here affected by uredospotic pustules. The teleutospores here, unlike the teleutospores on the *Launea*—from which they were subsequently found to differ extremely in size and shape—were covered by unbroken epidermis. *Launea nudicaulis* was not uncommon; *L. asplenifolia* was, in patches, plentiful. Both species were known as *pattal*, and the cultivators do not appear to distinguish between them; neither species was found to be diseased.

At Lahore, March 7th, early sown wheat was without "rust;" later sown had a good deal of the supposed *Puccinia rubigo-vera* but without teleutospores apparently; "rust" is here *khungi*. Both the species of *Launea* were found; *pattal* is a name here used only for *Launea nudicaulis*; *Launea asplenifolia* is termed either *pattal boti* or *dodak*—the last name has reference to its milky latex; the plant usually known as *dodak* is, however, the "Sow-thistle" (*Sonchus arvensis*). *Launea nudicaulis* was quite healthy; *Launea asplenifolia* was apparently healthy, but a number of plants were found with nodules developed in the axils of scales towards the top of the rootstock; these nodules were found to be filled with a mycelium.

At Gujranwala, March 8th, "rust" was plentiful, sometimes as at Ferozepur with teleutospores on nearly every affected plant; in these cases the uredospores were almost as plentiful on stems and outside of leaf-sheaths as on the leaves. In other fields, just as at Shibpur and at Mozufferpur, the uredospores appeared to be confined to the upper surface of the leaves and teleutospores were then absent. The only *Launea* present was *Launea nudicaulis*, sometimes called *dodak*, sometimes *pattal*. On its being pointed out that it has *not* milky juice, an informant insisted still that it was *one* of the *dodaks*; it is therefore possible that *Launea asplenifolia* may occur but was overlooked. This is not, however, certain; here not only the Sow-thistle, but also all the spurge are termed *dodak*.

There is not any evidence at present that *Launea asplenifolia* occurs in the Punjab west of Lahore. *Launea nudicaulis* occurs at Multan where it is known as *bhatal*; in Scinde; at Rawalpindi and at Mansehra in Hazara. But *Launea asplenifolia* recurs once more in the Kurram valley where it was collected by Dr. Aitchison; considering the peculiarly local nature of its distribution everywhere else, it is possible enough that it may occur in the Western Punjab, and may only have been hitherto overlooked. It occurs, too, in Scinde; within the past month it has for the first time been reported from near Karachi, where it is known as *bhantur*.

At Amritsar, March 9th, *Launea asplenifolia*, exceedingly local, was quite healthy. "Rust," here termed *khungi*, was very scarce; all of it the form of supposed *Puccinia rubigo-vera* with teleutospores. "Smut," termed *kanghari*, was extremely prevalent. *Launea asplenifolia* had no ascertainable name; *Launea nudicaulis* was not found.

At Gurdaspur, March 9th, "rust," *khungi*, was very scarce; *Launea asplenifolia* was not found; *L. nudicaulis*, termed *bhantal*, was rare.

At Amballa station, March 10th, *Launea nudicaulis* was seen.

At Saharanpur, March 11th, a good deal of rust, here still termed *khungi*, in local patches; mostly perfectly typical examples of the supposed *P. rubigo-vera*; one specimen was badly affected on the outer side of the leaf-sheath as well as on the leaf-blade; the "rust," in this case, was apparently quite different from any of the blights obtained elsewhere. Both *Launea asplenifolia* and *L. nudicaulis* are common; the former is, however, as usual, extremely local, the latter is general. They, like the rust, are still known by Panjabi names; *L. asplenifolia* is termed *bhantali* (feminine); *L. nudicaulis* is *bhantel* (masculine form). The spurge (*Euphorbia dracunculoides*) named *titlia* at Allahabad and Mogul Serai is here termed *dodi*. In the Herb. Saharanpur collection is a specimen of *Launea asplenifolia* collected between Jan and Pilkatra, Aligarh district, in December 1885, by Mr. J. F. Duthie, badly affected by the supposed *Puccinia rubigo-vera*; both uredospores and telentospores occur on the leaves; the æcidial fructifications are borne on specially modified shoots as in the Shibpur and Mozufferpur examples.

On the Rohilkhund and Kumaon Railway on March 14th, *Launea asplenifolia* was found in patches growing amongst kunkur "ballast" on the permanent way at the following stations: Pilibhit, Mailani, Gola Gokurnath, and Lakhimpur; at all of these

places *Launea nudicaulis* was also found. Both species were healthy everywhere except at Mailani, where *Launea asplenifolia* carried in plenty teleutosporic fructifications of the supposed *Puccinia rubigo-vera*; no uredospores and no æcidial fructifications were found. In Northern Oudh both the *Launeas* are known as *gobi*; the "rust" is *gerhwi*; in one place (Oel) the name *perhwi* was also used. At Sitapur, where wheat fields were examined, no "rust" was found, nor was either *Launea* obtained.

On this railway on March 15th, *Launea asplenifolia* was found in the permanent way at Kamalpur, Sidhauri, Ataria and Itaunja; in no case were diseased plants met with. From Itaunja onwards to Lucknow and at Lucknow itself only *Launea nudicaulis* was seen. But on the Oudh and Rohilkhund line *Launea asplenifolia* was again obtained, though not in a diseased state, at Safdarganj between Lucknow and Ajudhya, and at Malipur between Faizabad and Jaunpur.

At Meja Road on March 16th, the wheat had all been reaped; it was, however, reported to have had no rust. *Launea nudicaulis* was common everywhere. *Launea asplenifolia* was only found near Bandhwa village, but was there extremely abundant where it occurred and was much diseased; both uredospores and teleutospores were plentiful; no æcidial fructifications, however, were found.

On revisiting the wheat at Shibpur to search again—and again unsuccessfully—for teleutospores, it was discovered (March 21st) that, during the interval which had elapsed since the previous inspection (February 19th), the wheat had become affected by the supposed *Puccinia graminis*.

The initial stages of this outbreak were unfortunately not seen by us, but the condition presented by the field, when examined on March 21st, was very striking. In place of being the insignificant disease it had seemed in Upper India, attacking a plant here and there and then only to a quite trifling extent, the blight here was found to have attacked every plant in the field that had not been completely destroyed by the other "rust." Its uredospores, arranged in long oval pustules, occurred on both surfaces of every green leaf-blade, on the outside of every leaf-sheath, along the culms themselves; on the outside of the glumes and pales and even on the awns as far as their tips. A more striking contrast to the appearance of the same field when attacked by the supposed *P. rubigo-vera* than that now presented, could hardly be conceived. To render the contrast more effective, every plant of barley—which grain had remained immune from the other "rust"—was affected in precisely the way

and to precisely the extent that the wheat plants were affected. In this case too the relative immunity of the glutinous wheats against the earlier rust was of no avail; these indeed were the more severely rusted of the two classes, precisely because they had more healthy tissue left to be attacked than had the other wheats. A glance at the field in the condition it now was recalled at once the description given of an outbreak of rust some years ago at Khandwa, though it does not necessarily follow that it was *this* blight the cultivators were endeavouring to describe.

A search was at once instituted—and was continued almost daily till it became at length necessary to reap the wheat—for some local species apparently affected by this new “rust;” unfortunately up till now this search has been unsuccessful.

On closely examining the grain, however, it did not appear that this blight had done a great deal of harm. It must indeed have done some, but as it did not apparently tend to cause the leaves to wilt and wither to the extent observable with the supposed *Puccinia rubigo-vera*, the amount of harm could not fail to be less in this case than with the earlier ‘rust.’ In the case of those wheats with the leanest and most shrivelled grains, it was of course impossible to say that all the mischief had been done by the first blight; as, however, the barley, which had remained immune from the first one, ripened grain of a very fair quality though suffering so severely, to outward appearance, from the second rust, it is only reasonable to conclude that most of the mischief done to the wheat was done by the supposed *Puccinia rubigo-vera*.

The following are the principal distinctive features which characterise the various forms of rust occurring on wheat and barley that have been described above:—

I.—THE SHIBPUR RUST ON WHEAT.

Uredospores.—Sori circular or shortly oval, universally and evenly distributed over the upper surfaces of the leaves, warm yellow, pulverulent. Spores more or less circular, with elongated pedicels, and 4 to 5 germ-pores, echinulate, brilliant yellow, $24 \times 24 \mu$.

II.—THE MOZUFFERPUR RUST ON WHEAT AND BARLEY.

Uredospores.—Sori very large, elliptical or linear, much warmer orange than those of the Shibpur rust. Spores long oval, echinulate, orange, with 3 or 4 germ-pores situated equatorially, $34.4 \times 17.6 \mu$.

Teleutospores.—Sori of the same form as the uredosporic ones, warm brown, very soon exposed. Spores with long pedicels, which are frequently considerably dilated apically, fusiform, slightly constricted, usually greatly thickened terminally, occasionally obliquely truncate, sometimes greatly shortened and rounded, $44.8 \times 14.7 \mu$.

III.—FEROZEPUR RUST ON WHEAT.

Uredospores and Teleutospores presenting the features characteristic of *Puccinia rubigo-vera*.

One peculiarity presented itself in connection with what was apparently this form of rust as it occurred at Lahore, the uredospores being only feebly echinulate and occurring in two distinct series. In one the spores were relatively large, measuring $28.33 \times 25.6 \mu$, and were of a pale yellow colour, whilst in the other they were very much smaller, measuring only $17.6 \times 19.2 \mu$ and were of a brilliant orange hue. As there was an entire absence of any teleutospores, it was impossible definitely to determine whether, in this instance, the species were really *P. rubigo-vera* or not.

IV.—MOGUL SERAI RUST ON BARLEY.

Uredospores.—Sori narrow, oval or linear, of small size, arranged in elongated groups running parallel with the long axes of the leaves, very pale ochreous, late in becoming exposed.

Spores pyriform, with thick, moderately long pedicels, very pale yellow, echinulate, germ-pores very obscure, apparently only 1 or 2, $24 \times 17 \mu$.

V.—SAHARANPUR RUST ON WHEAT.

Uredospores.—Sori very large, greatly elongated. Spores more or less obovate, yellow, with from 9 to 13 germ-pores which are very conspicuous and irregularly scattered over the entire surface, measuring when mounted in Canada balsam $23.2 \times 17 \mu$, but no doubt considerably larger when in the fresh condition.

The rust occurring on *Launea*, and which may possibly be the source of the Shibpur rust on wheat, presented the following characters:—

Aecidiospores.—Pseudoperidia wide, shallow, deeply immersed, situate most abundantly on the lower surfaces of the leaves, but also occurring on the upper surfaces and on the axes. Spores yellow, almost circular, 20×20 to $24 \times 24 \mu$.

Spermogonia scattered over both surfaces of the leaves.

Uredospores echinulate, yellow, circular or shortly elliptical, germ-pores usually 3 but sometimes 4, and rarely 5 in number, irregularly scattered over the surface, 24×24 or $24 \times 19 \mu$.

Teleutospores very short-stalked, deep brown, relatively broad, often slightly curved, the terminal cell frequently obliquely truncate, $36 \times 27 \mu$.

In the only experiment on artificial infection of wheat which, owing to the early onset of extreme heat, it was possible to conduct, the procedure adopted was as follows:—Samples of wheat were sown in five pots, and after they had freely germinated, the young blades were sprayed with water in which the uredospores of the *Launea* rust had been diffused in large numbers. In four instances no signs of any infection followed, probably in consequence of the extreme aridity of the air evaporating the moisture before the spores had had time to germinate. In order to avoid this source of fallacy, in the remaining case the pot was covered by a bell-glass, the interior of which had been thoroughly moistened with spray, for a period of forty-eight hours after the application of the spores to the leaves, and here infection manifested itself a week later in the form of an eruption of scattered yellow sori on a considerable number of leaves. The characters of the sori and the uredospores that they contained were precisely those of the natural rust, and, had it not been for the possibility that a certain number of uredospores derived from the wheat, may have been adherent to the *Launea* leaves which furnished the infective material, the demonstration of the genetic relation between the two diseases would have been complete.

Reviewing briefly the results of the season's observations it is apparent in the first place that several blights of the nature of European "Rust" affect wheat in India.

Of these we may most advantageously consider first the rust that was originally observed in January on the wheat at Shibpur; for convenience of reference this will be spoken of as the "Shibpur Rust." The description given of its uredospores tallies so well, in spite of slight differences, with the description of the uredospores of *Puccinia rubigo-vera* given by Winter and by Plowright that, were there no other discrepancies, it might perhaps be sufficient to deal with it as only a form of that species. There is reason to believe, moreover, that this blight may form at least part of the "rust" tentatively referred to *P. rubigo-vera* by Dr. Barclay.

That it differs specifically from *P. rubigo-vera* appears to us to be, however, highly probable. The reasons for this doubt may be stated

in detail. First; in *P. rubigo-vera* the "rust" forms teleutospores on wheat; in this "Shibpur Rust" no teleutospores are formed on the wheat. It is true that a negative proposition is difficult to prove, and it may be objected that perhaps there were some teleutospores on the wheat which were overlooked.

This may, no doubt, be the case; we do not, however, think it probable; it must be recollected too that, wherever this particular "rust" was found, the same absence of teleutospores was experienced; and it should be remembered besides that, so far as the wheat itself was concerned, teleutospores were the main object of our search.

Again, this "Shibpur Rust" apparently has a different host. The æcidial fructifications in the case of *P. rubigo-vera* are carried by a "Borage"; in the case of the present species they appear to be borne upon a "Composite." The experimental infection of healthy wheat by the *Puccinia* on this "Composite" may indeed at first appear to be definite proof that this contention is sound. It must not, however, be overlooked that one very serious source of possible error exists. The composite from which the infective spores were obtained grew in a neighbourhood where there was undoubtedly rusted wheat. The conditions for the dispersal of spores were in this neighbourhood almost ideally perfect; it is therefore always possible that the spores which were obtained from the *Launea*, and which actually did infect the wheat, were not spores of the *Puccinia* that lives upon the *Launea*, but were spores from diseased wheat that had been accidentally carried to the leaves of the *Launea* and were lying there among the spores proper to itself.

To counteract this source of error specimens of *Launea*, bearing spores, were sent to Calcutta from various places in Upper India. If the same possibility of error prevailed at Mozufferpur, it certainly did not exist at Neemuch or at Jeypore. But the heat and dryness of the season unfortunately prevented any of these check-infections from being carried out; all the spores had in each case lost their vitality during the short time required for their transmission to Calcutta. It is to be hoped that, in another season, we or other workers may prove more successful.

If the suggested, and certainly possible, connection between the "Shibpur Rust" and the *Puccinia* on *Launea asplenifolia* be ultimately made out, the necessity for distinguishing this "Shibpur Rust" from *P. rubigo-vera* will have passed beyond the region of debate. For in the first place the *Launea* in this case bears uredospores, teleutospores and æcidia at the same time, whereas the "Borages" that act as hosts for *Puccinia rubigo-vera* carry æcidial fructifications only.

This remarkable difference may possibly be held to account also for the absence, in the case of the "Shibpur Rust," of teleutospores from the wheat. As if this were not sufficient distinction, it is seen that, though the uredospores of the two are very similar, their teleutospores are quite different.

But even if the absence of teleutospores from the wheat be held not absolutely proven, and if the connection between the "Shibpur rust" and the *Puccinia* on *Launea asplenifolia* be deemed yet a matter of doubt, we still have, as we believe, proof that the "Shibpur Rust" is not *P. rubigo-vera*, in the fact that the uredospores of the two rusts occur in pustules that differ markedly in form and in disposition.

The uredosporic pustules of *P. rubigo-vera* are described by Winter (*Rabenhorst, Kryptog. Flora*; i. pt. 1, p. 218) as elliptic to shortly-linear, whereas those of the "Shibpur Rust" are round. The pustules of *P. rubigo-vera* affect especially the leaf-sheaths and culms, the leaves, according to von Tubeuf (*Pflanzenkrankheiten*, 360), being much less affected, while they are figured by Oersted (*System der Pilze*, Deutsche Ausgabe, 24) as occurring on the glumes. In the Shibpur rust the disposition of the uredosporic pustules is quite the reverse of that indicated by Oersted and by von Tubeuf for *P. rubigo-vera*.

Another point to which we would direct attention is the fact that against this "Shibpur Rust" barley is immune; whereas, according to Plowright (*Brit. Uredineæ and Ustilagineæ*, 168), barley is one of the species affected by *P. rubigo-vera*. It must, however, be recollected that Winter (*loc. cit.* 218) only postulates the form described as *P. rubigo-vera* var. *simplex* Koernicke, as occurring on barley; in this he is followed by von Tubeuf (*loc. cit.* 360), and it is probable that this is Plowright's meaning also though he does not definitely express it; it will be necessary to allude to this point further on. In the meantime the life-history of this rust having been incompletely worked out, we refrain from proposing a new name to distinguish it.

We may next consider the rust that was first met with at Mozufferpur, but that was encountered in several other localities in Upper India and was found on the completion of the tour of inspection to be raging at Shibpur in March with all the violence displayed by the other rust in January and February.

That this, which for convenience we have termed the "Mozufferpur Rust," is the blight tentatively referred by Dr. Barclay to *P. graminis*, is undoubted. The true *P. graminis* is a species whose æcidial

fructifications are borne by one or more species of Barberry. In this case, however, the structural and metric features differ rather more markedly from those of true *P. graminis* than those of the Shibpur Rust do from the corresponding characters of *P. rubigo-vera*. The uredospores are decidedly narrower in the "Mozufferpur Rust" and, in place of having but two germ-pores, have an equatorial belt of germ-pores; the teleutospores are not, however, distinguishable except in forming pustules of a warm-brown colour, instead of black as in *P. graminis*. The most distinctive feature is again in the disposition of the pustules, which exactly as was the case with the Shibpur Rust and *P. rubigo-vera*, here reverse the conditions met with in *P. graminis*. In *P. graminis* the pustules are largely developed on the leaves; in the "Mozufferpur Rust" the pustules are confined almost entirely to the leaf-sheaths, culms and glumes. And while it is true that no plant has yet been found to carry the æcidia of this "Mozufferpur Rust," it is easier, and much more probable, to suppose that such a plant exists but has, so far, been overlooked, than to postulate that its spores are wind-borne to the wheat of the Indian plains from the Himalayas or the highlands of Central India, where alone "Barberries" are to be found. There is another strong reason for concluding that this "Mozufferpur Rust" cannot well be ordinary *P. graminis*; *P. graminis* is in Europe injurious to wheat, to rye, and especially to oats, less to barley (von Tubeuf, *Pflanzenkrankheiten*, 358). There were but few plants of oats present in the farm at Shibpur; none of these carried any rust. But this "Mozufferpur Rust" affected both wheat and barley to precisely the same extent, in exactly the same way and, apparently, with equal severity; whereas apparently only one particular form of *P. graminis* (*forma secalis*) has been found on barley (Eriksson und Henning, *Zeitschr. für Pflanzenkrankh.*, 1894, ii); this form occurs also on rye, whence the name, and on "Couch-grass," but has not been found on wheat at all.

The "Mozufferpur Rust," even in the very severe attack witnessed at Shibpur, did not appear to us to injure the plants to an extent at all corresponding to the amount of rust they carried; the grain whether of wheat or of barley did not seem to be greatly depreciated by its presence. It is difficult to compare this feature with the corresponding character of *P. graminis*; Plowright (*loc. cit.* 168) indicates that *P. graminis* is the more severe of the two leading wheat-rusts in England, whereas the experience on the continent of Europe appears to have been the reverse.

More difficult to deal with than either of the preceding blights is

undoubtedly that met with for the first time at Ferozepore and met with again at Gujranwala and at Amritsar, in which there were teleutospores as well as uredospores on the wheat.

The disposition of the uredosporic pustules in this blight was much the same as in the case of the Mozufferpur Rust, the outside of the leaf-sheaths and the outside of the culms being much more affected than the leaf-blades. But the uredospores themselves in this case differ altogether from those of the "Mozufferpur Rust," and the teleutospores, while differing as much as the uredospores do in structure, deviate still further, in that the teleutosporic pustules do not rupture the epidermis of the leaf or stem on which they occur, as those of the "Mozufferpur Rust" do. On the other hand this "Ferozepur Rust" has uredospores extremely like—indeed not distinguishable by tangible characters from—those of the "Shibpur Rust," and of the *Puccinia* as *Launea asplenifolia*. Still it does not follow that this "Ferozepur Rust" is the same as the "Shibpur Rust;" indeed the presumption is quite the reverse, since in this case we have a rust with teleutospores on wheat, in the "Shibpur Rust" one without teleutospores on the wheat. And it is certainly not the same *Puccinia* as is found on *Launea asplenifolia* for the teleutospores of the two are totally unlike. We must therefore have in this "Ferozepur Rust" either a very distinct manifestation of the 'Shibpur Rust,' and at the same time find in it a proof that the *Puccinia* on *Launea asplenifolia* is in no way connected with "rust" on wheat; or what, so far as the evidence at present available goes, is more probable, find in it a third "rust" on Indian wheat.

The structural and metric characters of the "Ferozepur Rust" agree so exactly with those credited to *P. rubigo-vera* by Oersted, Winter and Plowright, and the disposition of its pustules, except that none were found on the glumes, is so like the disposition of the pustules in *P. rubigo-vera* that we should have very little hesitation in identifying it with European species, but for the difficulty as to its æcidial fructification. No "Borages" have yet been discovered in India—though these have been long and diligently looked for by many competent observers—to carry any *Puccinia* whatever. And if this is at best but negative evidence, it still affords, in our opinion, an excellent reason for retaining an open mind regarding the point. It should be here observed that the "rust" obtained at Lahore, though teleutospores were not found, had its pustules disposed in the same manner as those of the "Ferozepur Rust" and not as in the "Shibpur Rust." As only the late sown wheat was rusted at Lahore, the absence of teleutospores may simply have been due to

their not having yet been formed. Still as has been noted already, the pustules present were very peculiar in containing spores of two quite different sizes.

There is unfortunately as yet no collateral evidence available regarding the relationship of this "Ferozepur Rust" to barley or to other grasses. And there is not as yet any means of judging whether this "Ferozepur Rust," or the "Shibpur Rust" with similar uredospores, is the more destructive to the wheat crop.

It has been already recorded that on one plant of barley at Mozufferpur in North Behar, and again on many plants of barley at Mogul Serai in the North-Western Provinces, a rust was found, the leading features of which were that the very small lemon-yellow uredosporic pustules lay arranged in many parallel longitudinal rows on the leaf-blades. This rust was only met with on these two occasions; because it happened to be more plentiful at that place, we have termed it the "Mogul Serai Rust." No teleutospores were found. The rust appeared to do no tangible harm even at Mozufferpur, where the conditions had evidently not been unfavourable to the development of at least the "Shibpur Rust." It does not, however, follow that under all circumstances this need remain equally harmless, and though it has not as yet been met with on wheat, it is nevertheless a "rust" that must be reckoned with in any subsequent enquiry.

Regarding its possible identity little can be said. It certainly appears to us impossible to refer it either to the Shibpur blight or to the Mozufferpur one, still less to the Ferozepur blight. Future workers may find it advisable to compare it with a little understood European *Puccinia*, also like this one apparently confined to barley, of which the æcidial fructification and the intermediate host are equally unknown. The rust in question is one that was differentiated by Fueckel (*Symbol. Nachtr.* ii. 16) as *Puccinia Hordei* and by Rostrock (*Herb. Mycet. Oeconom.* n. 451) as *P. anomala*, but was afterwards supposed by Koernicke (*Land- und Forstw. Zeitung*, 1865, n. 50) to be only a variety (var. *simplex*) of *P. rubigo-vera*. Winter agrees (*loc. cit.*) with Koernicke; Plowright (*loc. cit.*) apparently does the same. Eriksson and Henning (*loc. cit.*) have returned to Fueckel's view, and treat it as a distinct species. Von Tubeuf, with a fine impartiality, adopts both views and enumerates the rust twice. But it will be apparent from this divergence of view that even this European *Puccinia* is hardly completely understood.

Finally the very distinct rust met with only at Saharanpur and only on one plant has to be referred to. This "Saharanpur Rust" differed markedly from all the other specimens obtained, in the dis-

position of its pustules. In place of being circumscribed areas these consisted of linear streaks, sometimes several inches in length, along the culms and along the outside of the leaf-sheaths. Whether this rust affects the glumes cannot be said, for it was only found on one plant, and as it happened that plant had every head destroyed by *ustilago*. The plant, strange to say, was apparently quite vigorous; this, coupled with the general appearance of the rusted spots, led to the belief at the moment of gathering, that it was but an extreme example of the "Mozufferpur Rust" in which the pustules had become confluent. But when minutely examined it was found that it has nothing whatever to do with the "Mozufferpur Rust;" it differs entirely as regards uredospores and has no teleutospores. The uredospores are also extremely different both from those of the "Shibpur Rust" and of those the "Ferozepur Rust." From the latter it differs moreover in having no teleutospores at all; from both it differs in having uredospores with an unusually large number of germ-pores. Whether it be capable of affecting barley is as yet unknown. It is, however, clear that there is a fifth rust—the fourth occurring on wheat in the plains of India—the life-history of which requires further investigation before the subject of rust on wheat in India is fully understood.

Any consideration of the question of the relationship of the geographical distribution of *Launea asplenifolia* to the wheat-growing area is almost premature, in view of the fact that the connection between the *Puccinia* which this *Launea* carries and one of the rusts on wheat, has not been definitely demonstrated.

It is well known, for example, that in years when rust attacks wheat in the Central Provinces, its ravages are excessive. Yet in the Central Provinces no examples of *Launea asplenifolia* were obtained. Too much stress should not be laid upon this point for several reasons. It is, to begin with, a matter capable of experimental demonstration whether this connection exists or not. If it be proved that it does exist, the observations made during the present season need not give rise to any great difficulty. There is no reason why a rust, under suitable conditions may not, after having once started from a focus of infection in the shape of a diseased *Launea* patch, travel by direct infection in a very brief period from one end of a province to another. But it does not follow because it was not found in the Central Provinces that *Launea asplenifolia* does not occur there. It is a species that, though always plentiful where it occurs, has an exceedingly "local" distribution, and it is conceivable that it may exist and yet have been overlooked. Again though

Launea asplenifolia was not found, another species of *Launea* was ascertained to be general in the Central Provinces; this species was in Rajputana discovered to be capable of carrying at least one stage of this blight. Then it is now known that *Launea asplenifolia* occurs at Ujain, which means that, further to the west, it occurs as far south as, and in precisely the soil it would find at, Jabalpur. And, besides, it does not follow that the blight most destructive in one place or in a given season is that most destructive elsewhere or in another season. The cultivators questioned regarding the probable cause of the "rusting" at Mozuffarpur, insisted that the meteorological conditions of the past cold-season never failed to induce it. At Gaya, on the other hand, the belief was that conditions such as were experienced last cold-weather are precisely those that ensure exemption from the blight. One possible explanation of this discrepancy is doubtless that the blights which the cultivators had in their minds may be different ones. But this is certainly not the only explanation, and in no case is it quite a sufficient one. Fortunately for the cultivator, but unfortunately for our enquiry, there was practically no rust this year outside Bengal and North Behar. But even during the journey described above, it was possible this year to discover that different blights may on occasions lead to practical destruction of the wheat crop. At Maharajpur near Jabalpur a cultivator described with all the accuracy born of familiar and sad experience the wilting and inrolling of the tuft of leaves at the base of the young wheat plant, the rusty spotting of the leaves above, the reddening of the ground and the shrivelling of the grain characteristic of the Shibpur blight. "It ate up the fields like fire" was the striking phrase with which he concluded his narrative of the last rust epidemic in Central India.

At Khandwa, on the other hand, the wheat being there also this year equally free from rust, the cultivators described the onset and progress of their last epidemic in altogether different terms, and though the force of the account was not at the time appreciated, the moment the wheat-field at Shibpur, when under the full influence of the "Mozufferpur Rust," was seen, it was realized that the Khandwa account may have been as graphic and probably as accurate as the account obtained at Jabalpur, since here too was a prevalent blight with general features quite as striking as, and yet totally unlike, those of the earlier one. It did not, however, follow that what had been described at Khandwa was this particular rust. On the contrary the fact that this—the Mozufferpur Rust—does not apparently, even in bad cases, very seriously affect the health of the plant, whereas the blight described by the cultivators at Khandwa was said to have

completely ruined their crop, leads rather to the conclusion that the Khandwa rust must have been different from the Mozufferpur one ; it may possibly have been the " Ferozepur Rust " which, as we have indicated, closely resembles true *P. rubigo-vera* if it be not actually that species. In true *P. rubigo-vera* the glumes are covered with pustules, precisely as the Khandwa cultivators described ; it is true that no pustules were found on the glumes in the Punjab this season ; it must, however, be recollected that rust in the Panjab was this year almost everywhere scarce and hardly anywhere severe.

Even if it be ultimately possible to definitely associate the *Puccinia* on *Launea asplenifolia* with one of the rusts on Indian wheat, and even if that rust should prove to be the most destructive of all the rusts that occur on wheat in the plains of India, it is somewhat difficult to suggest any remedial measure. There is, of course, but one that could be of any real benefit—the extirpation of *Launea asplenifolia*. But it will, we think, be plain, from the account we have given of its structure and of its distribution, that this must prove practically an impossible undertaking.

Even if *Launea asplenifolia* were eradicated, the source of but one blight would be removed ; and in the meantime it is necessary to wait for verification or the reverse of the connection mentioned as possible in the case of the Shibpur blight, and for further knowledge regarding the other rusts before active measures are advocated.

